Bidirectional Reflectance Distribution Function measurements on Single and Multiple layered Oil Paint Structures

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1. Introduction

Bidirectional Reflectance Distribution Function (BRDF) measurements have been carried out on oil paint samples in order to determine their spectral and angular distribution of the reflectance. The gonio-spectrophotometer setup at the CSIC (Figure 1) was used and provided BRDF data as well as CIELab data on the colour of the paint samples. The results show that it is possible to measure the BRDF and CIELab data of oil paint. Differences can be observed when comparing the reflectance of paint and paint with a glaze applied on top of it. The results as well indicate a clear difference in the acquired data which is caused by the substrate on which the paint was applied.

2. Experiment

The BRDF measurements were carried out using the system shown in Figure 1. The light source is a Xenon lamp which irradiates the surface of the sample through the Köhler system and a periscope setup indicated in the image. The sample is attached to the robot arm using a vacuum sucker and the robot arm makes it possible to move and align the sample in multiple directions. The spectrophotometer (SR) detects the reflected light in a range in the visible spectrum (380 nm to 780 nm) and it set to a variable field view of 1°. The instrument is mounted onto the cog wheel and travels along this wheel during the measurements [1].

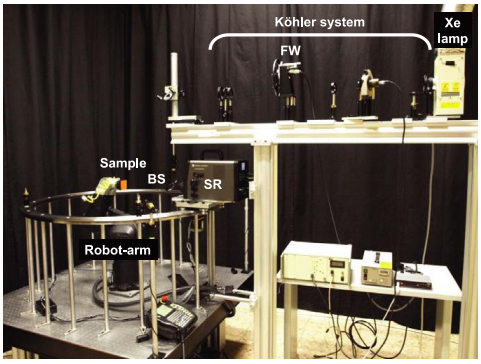

Figure 1: Setup of the system used to measure the BRDF and CIELab colour data.[1]

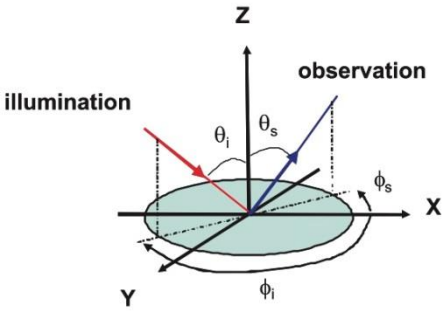

Figure 2: Sample coordinate system indicating the illumination (θ_i, ϕ_i) and observation angles (θ_r, ϕ_r) in spherical coordinates.

	Measured angles	Number of geometries
Illumination angle θ_i	15°, 45°, 75°	3
Observation angle θ_r	0° - 75° with 5° steps	16
Illumination angle ϕ_i	0°	1
Observation angle ϕ_r	0°, 180°	2

Table 1: Measured geometries with the different illumination and observation angles applied in this research.

The measurements were done for varying illumination and observation angles (Figure 2, Table 1). Three illumination angles were chosen in combination with two times 16 observation angles resulting in 96 measured geometries. The used geometries are listed in Table 1 where a θ angle of 0° is perpendicular to the sample surface. The samples are six different oil paints which are applied on Leneta opacity charts (type 5C and 2A2), on microscope slides and canvas board. The colours of the paints are yellow (weld pigment), blue (indigo pigment), black (charcoal black) and green (mixture of yellow and blue).

3. Results

The results of the BRDF measurements show the spectral distribution of the BRDF indicating the reflected light per wavelength, this is also a measure for the colour of the paint. The spectra in Figure 3 show a clear difference between the BRDFs of paint applied on the black area of the opacity chart and the paint applied on the white area. The paint on the white area reflects more light. A glaze layer applied on top of black paint results in a lower BRDF compared to only the black paint for specific illumination and observation angles (Figure 4). This results in the glaze layer on top of black paint appearing darker compared to only the black paint.

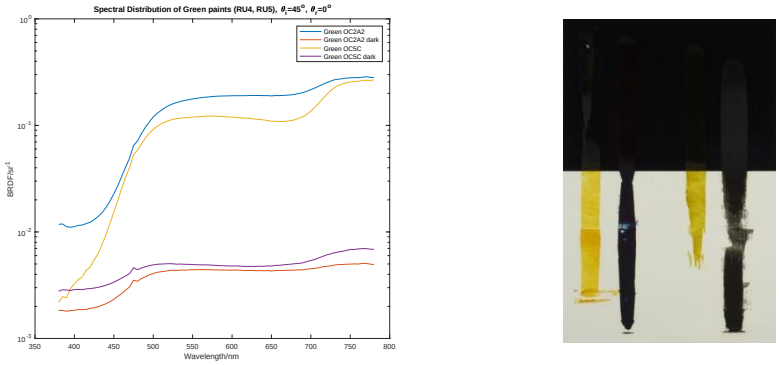

Figure 3: Left: Spectral distributions of BRDF for four different measurements. Green paints (mixtures of weld and indigo) on the black area (dark) and white area of both Leneta opacity charts. Right: Leneta opacity chart 5C with weld, indigo, green mixture of weld and indigo and charcoal black.

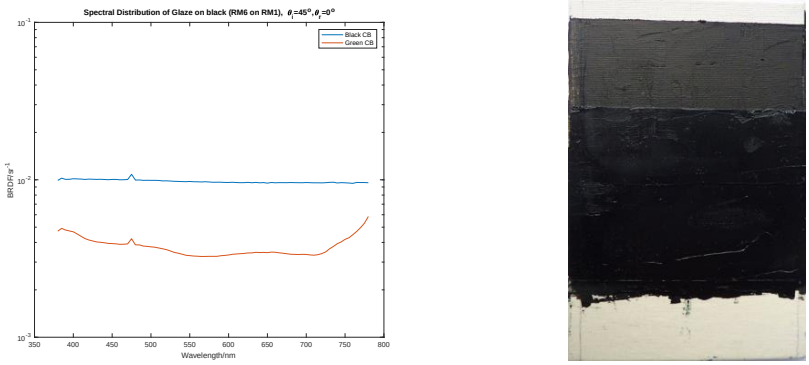

Figure 4: Left: Spectral distributions of BRDF for green glaze applied on black paint (red) and only black paint (blue). The glaze shows a lower BRDF value compared to the black paint indication larger appearance of the glaze. Right: Canvas board with on the top black paint and below that glaze applied on top of the black paint.

The angular distribution of the BRDF measurements for the three different illumination angles shown in Figure 5 is indicating a small specular element for most of the green paints. A higher specular is measured for the green paint applied on the black area of the opacity chart. The absence of a specular indicates a diffuse reflection.

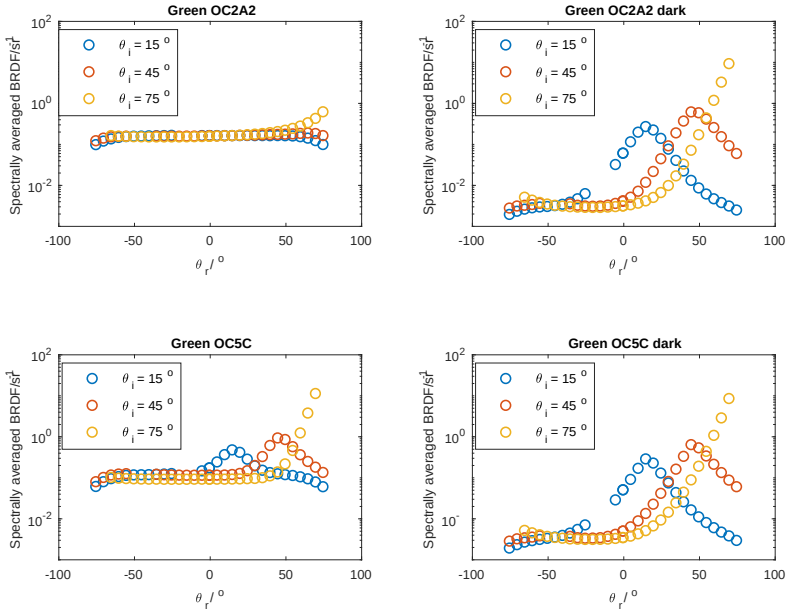

Figure 5: Angular distribution of BRDFs measured for green paint on opacity chart. Left the paint on the white area and right the paint applied on the black area. Measurements done for illumination angles of 15°, 45° and 75°.

CIELab data were retrieved from the BDRF measurements indicating the colours of the measured paint samples in the CIELab diagram. Interesting here is that the a* and b* values differ for the same paint applied on different substrates (Figure 6).

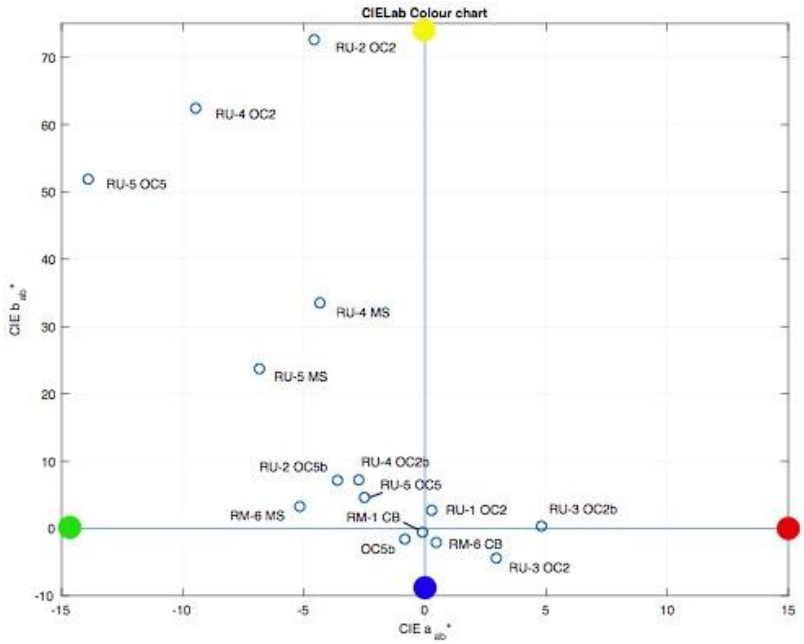

Figure 6: CIELab colour chart indicating the a* and b* values for each measured sample.

4. Discussion

In the results section it can be seen that the BRDF data shows differences in reflectance for different angles. Because isotropy of the painted surface was assumed, measurements were done with a limited amount of geometries and therefore in a relatively low resolution. The result is that the data is only valid for one plane within the half sphere. To test whether isotropy is a valid assumption, measurements should be done for more geometries.

The colorimetric data used to create the CIELab chart in Figure 6 shows that the surface on which the paint is applied influences the measured colour of the paint. The translucency of the paint and glaze could be the reason for the influence of the background. Next to the influence on the colour, the translucency also determines how the light is reflected due to the interaction of the paint with the light. BRDF measurements are a proper indication for the reflected light from the surface of a paint and glaze layer. BRDF measurements only give an indication of the reflected light from the surface of the paint layer. For that reason, BSSRDF (Bidirectional Scattering-Surface Reflectance Distribution Function) or BTDF (Bidirectional Transmittance Distribution Function) measurements could be an option for more accurate data on the behaviour of light underneath the surface of the paint.

5. Conclusion

BRDF measurements of oil paint samples and glazes give a clear indication of the reflection of light from the surface. A glaze layer applied on top of a black paint layer reflects less light in specific angles compared to only the black paint. This effect is clearly visible in the BRDF data which also indicates specular and more diffuse reflection from the paint samples. The measurements done give colorimetric data of the samples, showing differences in the colour of a same sample on different surfaces. Next to the influence of the background on the colour, the background influences the amount of reflected light as well. This could be an indication that the translucency of the paint and glaze influences how light interacts with the paint and therefore the reflection of light. In order to determine this effect, more measurements should be done, for example BTDF.

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